Smart Waste Management in Modern Cities

Final Report

1. Introduction

Modern cities face challenges in waste management due to the growing population and increasing urbanization. Traditional waste collection methods can be inefficient and labor-intensive. This project aims to address these challenges by developing a machine learning-based approach to detect and localize waste in urban environments. The goal is to automate waste detection, which can aid in more efficient waste management systems and even assist in waste segregation.

2. Approaches Followed

Initially, I experimented with MobileNet as the backbone for my model due to its lightweight nature, making it suitable for real-time applications. The model was trained to classify different types of waste and localize it in the image using bounding boxes. The model included two components:

1. **Waste Classification:** A classification layer that identifies the type of waste.
2. **Bounding Box Regression:** A layer that predicts the coordinates of bounding boxes around the detected waste.

However, the IoU performance with MobileNet was suboptimal, yielding only a 0.345 IoU. After evaluating the results, I switched to **ResNet-34**, a deeper architecture that showed better performance, increasing the IoU to 0.4658. The model was trained using mixed precision to speed up the training process.

3. Limitations of Followed Approaches

While ResNet-34 provided an improvement, it still faced certain limitations:

- **Bounding Box Regression:** The bounding boxes sometimes had inaccuracies, particularly with smaller or obscured waste objects.
- **Model Generalization:** The model was trained on a specific dataset, which could affect its performance in more varied real-world scenarios, especially with unusual waste types.
- **Dataset Quality:** Inconsistent or noisy labels in the dataset might have impacted the accuracy of both classification and localization tasks.
- **Computation:** Although the model was trained with mixed precision, the deeper ResNet-34 model requires more computational resources compared to MobileNet, which might limit its use in resource-constrained environments.

4. Quantitative Results

The model achieved the following results:

- **F1-Score:** 1.0, which indicates perfect precision and recall for the waste classification task.
- **IoU:** 0.4658, which shows that the model is reasonably good at localizing the waste within bounding boxes, though improvements can still be made, especially for crowded or small objects.

These results suggest that the model is capable of accurately detecting and localizing waste in urban images, though there is room for improvement in bounding box accuracy.

5. Qualitative Results

The qualitative results show that the model generally performs well in detecting waste in images with clear backgrounds and well-defined objects. The bounding boxes typically align with the visible waste. However, in cluttered scenes or when objects are partially obscured, the bounding boxes become less accurate. Some images might also show the model struggling to identify small waste items or objects that are difficult to classify due to unusual shapes or types.

6. Observations

- The **model's performance** is highly dependent on the clarity of the images. In cluttered or noisy scenes, the model's IoU drops, but it still provides useful predictions about the location of waste.
- **Future work** could focus on improving the bounding box regression to handle challenging cases like small or overlapping objects. Techniques such as region-based CNNs or attention mechanisms could be explored to better localize waste in these situations.
- **Data augmentation** could help improve the model's generalization to more diverse images, reducing the risk of overfitting to the training dataset.

Conclusion: This project demonstrates the potential of machine learning in solving urban waste management challenges. By using models like ResNet-34, we can effectively detect and localize waste in images, paving the way for more automated waste management solutions in the future.